NASA TT F-11,742

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GPO PRICE $ _____

CFSTI PRICE(S) $ _____

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

FACILITY FORM 602

N68-25845 (ACCESSION NUMBER) (THRU) 1

36 (PAGES) (CODE) 20

[redacted] (NASA CR OR TMX OR AD NUMBER) (CATEGORY)

Translation of "Campagne Eole-Pacifique IV (Ière Partie)".
Service d'Aeronomie, Centre National de La Recherche Scientifique, Verrieres, 25 March 1968, 49 p.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON MAY 1968

NASA TT F-11,742

EOLE-PACIFIC 1V FIELD EXERCISE

(First Part)

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Read and approved by the Director
of the Aeronomy Service
J. E. BLAMONT

s/ J. E. BLAMONT

Verrières, 25 March 1968

No. 179

EOLE-PACIFIC IV FIELD EXERCISE (1st Part)

P. Morel, et al

1. INTRODUCTION

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The EOLE-PACIFIC IV (EP-IV) field exercise is the third undertaken by CNRS (Centre National d'Etudes Spatiale; National Center for Space Studies) in preparation for the EOLE test. The main objective of this expedition has been scientific in nature: to study the progressive scattering of groups of sounding balloons released simultaneously and, in this manner, to determine in what measure the trajectory of a single tracer is representative of the movement of that portion of the air in which it is carried.

To this principal objective was added several technological objectives such as the releasing of the balloons at an accelerated rate (4 per hour), the storing of the balloons prepared for flight in the ZODIAC shelter as anticipated in the EOLE balloon launching stations, and above all the flight testing of the thermistor thermometer scheduled for EOLE. This portion of the exercise has obviously been of an exploratory nature, particularly since EP-IV was the first chance for using the new beacons constructed as a result of information gathered from EP-I (July 1966). Appendix I is devoted to a detailed description of the technology tested and the results of the flights. Out of a total of 29 balloons which were released only one carried a radar reflector.

The site chosen, the MILDURA meteorological station (142° East, 34° South), was designated by the Australian Bureau of Meteorology for these tests. This station is in fact the one from which the stratosphere balloons of the HIBAL Project are released (University of Melbourne). This location with median latitude has permitted, as expected, placing the balloons in the midst of the general circulation from the West. It has excellent sunny conditions and an almost total absence of cloud covering, a necessary requirement for grouped flights. On the other hand, the force of the wind at ground level often hindered and even prevented the launchings.

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The scientific and technical help of the Australian Bureau of Meteorology has been very valuable for the success of the mission. The meteorological charts of the various standard altitudes prepared daily by the Bureau were extremely useful in organizing the flight program and indispensable in interpreting the results in relation to this area of Australia. In addition, the

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* Numbers in the margin indicate pagination in the original foreign text.

personnel of the MILDURA meteorological station helped the mission in an abundance of good will and, in particular, accomplished several radar recordings of the soundings.

2. CLIMATE AT THE MILDURA SITE /4

The meteorological station at MILDURA is located at 34° latitude South and 142° longitude East, sufficiently far to the West of the mountain chain which separates the bordering humid region from the great Australian desert. Alone, the presence of the Murray River lessens the semi-desert atmosphere of the region by giving permanent irrigation.

The bordering chain isolates Mildura well from marine influences and without exception (wind from the South-West) the sky is remarkably clear and free from clouds as is the rule in sub-tropical arid zones. During a period of one month only four days of rain in the form of a shower were recorded.

The atmosphere is therefore generally very dry above two kilometers, the lower layer alone containing an appreciable quantity of water. The humidity at ground level varies in relation to the temperature, approaching the saturation point at dawn (90%) and falling to 30% in the middle of the afternoon. The Mildura site therefore appears particularly favorable due to the prolonged absence of dense cloud covering (as opposed to the bordering zone which is partially or totally covered during the major portion of the month).

On the other hand, this location in the middle of a plain rigorously /5 lacking in contour is particularly exposed to the wind, the least acceleration of the circulation in the limited layer provoking a violent and irregular wind at ground level (average 20-30 knots, gusts up to 40 knots). The great temperature contrast between the day (30° C) and the night (15° C) occasionally causes a prolonged calming of the wind at dawn or twilight. The morning calm can begin at 03 or 04 hours and generally ends a short time after the rising of the sun (06 hours). In similar fashion, the evening calm takes place after the setting of the sun (20 hours) and can last until 22 or 23 hours. These periods are the only ones favorable for releasing tight balloons whose ascending speed is slow (2 to 3 meters per second). These periods unfortunately were rare during the field exercise and it was necessary to release the balloons under mediocre conditions, thereby risking possible damage to the balloon or the pay load. Several disturbances (three in a month) produced an appreciable and prolonged increase in the ground wind prohibiting all releases during three or four days in succession. These disturbances particularly hindered the releasing of the grouped flight program.

TABLE I shows the collected data characterizing the changes in ground wind during the month of December 1967 and the beginning of January 1968. The speeds indicated (1 knot = 0.5 meters per second) concern the wind at an altitude of 15 meters above the earth. The value indicated "average" is a /6 typical speed about noon (day) or midnight (night). The value "maximum" is the speed at the height of the gusts. The difference between the values "maximum" and "average" characterizes, therefore, the irregularity of the wind. It should be noted that "maximum" speed is generally double that of "average" speed. The duration indicated for morning and evening calms is that period during which the wind at 15 meters above the earth does not exceed six knots or three meters per second, this speed being the limit at which the launching of a tight balloon does not present any problems. Note the frequest absences of pronounced calm in the morning as well as in the evening.

3. INSTALLATION /8

The location chosen for preparing and launching the balloons was on the edge of the main landing field on the terrain at MILDURA. This location which was well detached at a distance of approximately 50 meters was unfortunately circled by a belt of low shrubs whose presence complicated several launchings, particularly with the balloon which had very long pay load floats at the end of a 40 to 80 meter line. In addition, the shelter was headed in the direction of the dominant winds (SW-NE) but the majority of the launchings were made in a South or South-East wind, which meant it was blowing across the shelter.

Shelter for the Balloons

The operations for inflating and checking the tightness of the balloons was done in an inflatable frame ZODIAC shelter, 20 x 10 meters in size, placed at our disposal by CNES. This light shelter demonstrated itself to be reasonably satisfactory for handling the balloons.

The shelter suffers however, for this purpose, from noticeable faults:

-- the shelter is not completely tight and allows dust raised by the wind to easily penetrate it,

-- the sides are not sufficiently rigid and beat violently as soon as the /9 wind rises. In fact, this shelter has been demonstrated as perfect for winds (at a height of 15 meters) less than 10 knots; acceptable for winds from 10 to 20 knots; and dangerous for winds above 20 knots,

-- the doors securing the two ends of the shelter are not large enough to easily get a balloon 2.50 meters through. The lower extremity of the bag had to be dragged along the ground and the upper part of the balloon

TABLE I

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DATE	DAILY AVERAGE (knots)	DAILY MAXIMUM (knots)	EVENING CALM (duration, hours)	NIGHT AVERAGE (knots)	NIGHT MAXIMUM (knots)	MORNING CALM (duration, hours)
1/12/67	10	22	3	6	12	0
2	10	24	0	12	24	0.5
3	13	26	0	10	20	0
4	13	24	0	11	20	0
5	10	24	3	6	12	0
6	7	16	1.5	10	16	0
7	10	20	0	11	22	0
8	8	22	7	7	13	2.5
9	6	20	5.5	9	14	0
10	14	28	2	7	18	2
11	6	16	0	16	32	0
12	20	44	0	8	18	0
13	10	20	0	11	20	1
14	15	30	0	6	10	3
15	14	32	0	6	13	0
16	4	16	4	7	14	3
17	10	24	2	10	24	0
18	18	26	0	10	22	0
19	14	26	0	6	14	0
20	10	20	1.5	7	15	0
21	12	24	0	9	18	0
22	13	26	0	9	20	0
23	10	24	3.5	6	12	0
24	6	26	0	6	12	0
25	8	20	3.5	7	12	2.5
26	6	16	2.5	6	9	1
27	12	28	0.5	8	20	0
28	8	20	0.5	12	24	2
29	12	30	0	14	30	0

TABLE I (continued)

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DATE	DAILY AVERAGE (knots)	DAILY MAXIMUM (knots)	EVENING CALM (duration, hours)	NIGHT AVERAGE (knots)	NIGHT MAXIMUM (knots)	MORNING CALM (duration, hours)
30/12/67	20	44	0	10	24	0
31	10	22	0	8	22	3
1/01/68	10	20	0	6	18	2
2	8	20	0	14	30	1.5
3	5	10	5	10	26	0
4	9	18	6	10	20	0
5	10	20	0	7	14	3
6	8	20	3.5	5	7	6
7	9	22	0	5	9	2
8	6	16	3	8	12	0
9	14	26	0	10	24	0
10	14	26	0	10	24	0
11	10	22	0	12	22	0
12	12	30	0	10	18	0

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still was not entirely prevented from rubbing on the door,

-- the sides of the door or exit are extremely cumbersome with various ropes and stay wires. This situation causes some hindrance in releases during a cross wind, which is unfortunately frequent,

-- the movement (setting up - taking down) of the doors requires an unusually great amount of muscular energy. It is impossible for one person to do it alone.

The shelter was put up in two days on a cleared but not specially prepared site. This shelter was demonstrated to be adequate for storing and unpacking the materiel, for verifying the tightness of the balloons, and in a general way for preparing the flights during calm periods (wind less than /10
20 knots). The ZODIAC shelter, therefore, presents an easy and efficient solution for all temporary or field exercise installations where it would be possible to halt the operations when the wind rises. On the other hand, this shelter does not allow either for preparing the flights or conveniently storing the unpacked bags if the ground wind exceeds 20 knots (on the subject see the chapter "Preparation of Balloons").

The shelter does not allow, in any case, detailed work such as the assembling of electronic beacons, wiring, or the listening for signals which requires calm quiet conditions and great cleanliness. A rigid shelter is indispensable for this work (or even a transportable "shelter").

Reception Station Antenna

The reception station includes two COLLINS 51-S receivers and a vertical monopole $\lambda/4$ antenna mounted on a flat reflector made up of the metallic roof of the Meteorological Station building.

A reception test was made with another antenna (dipole $\lambda/2$) mounted horizontally between two pylons. This second antenna was demonstrated as less satisfactory in performance than the vertical monopole.

In general, conditions for radio-electronic reception during the course of EP-IV were appreciably inferior to those encountered at the Tontouta /11
Airfield (New Caledonia) during July - August 1966.

4. PREPARATION AND LAUNCHING OF THE BALLOONS

4.1 Unpacking Procedures

The bags were rolled like a spindle and then each was rolled in a cardboard cylinder 15 centimeters in diameter and secured directly to the packing case (two bags per case). This very careful method of packaging has not

shown a decisive improvement in relation to former packaging since after being transported by air freight and truck (1000 kilometers from Melbourne to Mildura), an average of 0.5 leaks per balloon were found on unpacking. Under these conditions, a systematic test for tightness before launching still remains necessary. Concerning this subject we note that the leaks discovered under these conditions are generally large and would have produced the failure of the balloon in less than 24 hours (loss: 1 cubic centimeter per second). In addition, on several occasions leaks were discovered at the site from rivets set during the course of manufacture: rivets detached or crushed, which led us to believe that these parts were placed on the mylar before total loosening of the shaping restraints. 12/ In other words, the rivet when set in material having a certain residual stretch blows out when the plastic returns to its original size.

It should be noted, in addition, that the threads of numerous nylon valves had been forced.

4.2 Preparation of Simultaneous Flights

The procedures from the unpacking to the launching of a balloon lasts three to four hours. Therefore it is impossible to launch several balloons in rapid succession unless they are completely prepared before the launching operations begin. This procedure, under the field exercise conditions at Mildura, caused a great difficulty since it was necessary to store the prepared bags during a more or less prolonged period if meteorological conditions at the scheduled hour were unacceptable for launching. Therefore a storage problem was encountered where "holds" were necessary during the preparation process in order to wait for favorable meteorological conditions, possibly several days.

The sequence of operations for preparation of four balloons and the possible holding points are as follows: 13/

-- unpacking and dry air inflation in order to reach p. + 50 millibars pressure,

-- looking for and marking possible leaks in a tub of water,

-- deflation to p. + 5 millibars and repairing of leaks with rivets of mylar, hot glued,

-- inflation to p.+ 50 millibars and verification of the tightness of set rivets.

Hold A

Completion of these operations takes approximately three hours for one balloon and six hours for four balloons handled in a series. It is found that with the balloons inflated with air they can be kept in good condition safely

(the material of the bag is not strained) on condition that there is constant surveillance of the pressure which can vary appreciably (+ 25 millibars) because of temperature variation in the shelter. There is here at this point, therefore, the first possibility of holding the operation ("Hold A"). This hold can be scheduled approximately two hours before the launching if it is decided to follow operations (H - 120):

-- completely empty the bag of the air which it contains with the help of/14 a hemispheric hamper,

-- partially inflate the bag with helium in order to give a slight lifting power to the bag alone.

Hold B

There is a second possibility of holding here since the bag itself is supported by the helium, requiring a minimum of mechanical effort, and can be preserved without damage in a calm atmosphere (example: Lally, field exercise 1966). The time schedule for Hold B is therefore set at approximately at H - 60.

-- Final inflation and adjustment of the helium contained by weight for the lifting force of the balloon.

Hold C

Note that the lifting force is on the order of one kilogram for a 200 millibar flight and 2.2 kilograms for a 300 millibar flight. There is, therefore, not a negligible force on the lower polar tip of the bag. Nevertheless it can be foreseen that the balloons can be retained in this condition: Hold C at approximately H - 30. All future operations (mounting and fastening the recorders, etc.) proceeding up until launching give less chance of pro- /15 ducing leaks and consequent resumption of initial operations.

-- mounting of the recorders on the balloon (thermistor, differential manometer) and sealing (special 3M cement),

-- fastening of the harness (various wires and cables) on and under the balloon,

-- deployment of the pay load: electronic beacon 5 to 10 meters beneath the balloon, possibly air recorders (thermistors) and float at the end of a 40 to 50 meter cable.

-- opening the door of the shelter,

-- launching.

The dilemma, therefore, is the decision of either holding the preparation at stage A and finishing the final phase at least two hours before the hour of scheduled launching or keeping the bags waiting at stage B or C. Hold C was first attempted with very poor results since at approximately 10 knots, the wind shook the shelter and the half-inflated balloons which were inside. In fact, the test was very severe since an unannounced disturbance forced a hold lasting 36 hours while the wind whistled at 20 knots with some gusts of 30 to 40 knots. After this period during which the material was strained in an obvious manner (balloons oscillating rather violently around their moorings) it was found that four bags out of four were pierced by a large number of leaks. 16/

Balloons	Number of Leaks when unpacked	Number of Leaks after 36 hours storage at Hold C (gales 30-40 kt)
GNGS	1	25
CDCR	0	20
UBUF	0	15
NCNP	0	9

It is interesting to note that the majority of the leaks were found on the upper hemisphere of the balloon, near the equator, or at the cracks in the creases of a half-inflated balloon (Figure 1). No leaks appeared close to the fastening point which underwent a pull of from two to four kilograms during the wind gusts.

It is expected that this material fatigue can be remedied by inflating the bag just enough to make it float almost freely balanced inside the shelter (Stage B). This method, however, has not solved the problem as expected since another group of four balloons held waiting in this stage for 36 hours during some 30 knot gales were also damaged. 17/

This experience has permitted verification of the possibility of holding a balloon without damage provided that it is almost entirely inflated (no creases).

Balloon	Number of Leaks when unpacked	Number of Leaks after 36 hours storage - Stage B (gales 30 kt)	Number of Leaks after 24 hours completely inflated
BVBW	1	17*	1
RCRP	0	1	not tested
NVNW	0	1	0
BLBG	1	10	0

* The BVBW balloon was detached from its mooring and was cemented to the ceiling of the shelter battered by the wind.

In conclusion, in order to keep an unpacked balloon during a relatively prolonged period without risking the chance of new leaks, it is necessary:

-- either to provide a perfectly tight rigid shelter in which the balloon can be left practically freely balanced, 18/

-- or to keep the balloons fully inflated with air or helium but in either case in a spherical shape.

4.3 Launching Conditions

The conditions for release during the course of this field exercise were found considerably less favorable than those during the preceding EP-I and II operations. The difficulties were evidentally the result of an unusual coincidence of calm periods with the absence of clouds. It was therefore necessary to launch in rather strong and irregular gales. In addition, the launching operations were often hindered by:

-- direction of the wind perpendicular to the axis of the shelter,

-- the door a bit low and a stay wire encumbering the passageway,

-- proximity of relatively elevated obstacles and shrubs.

Balloon	Number of leaks when unpacked	Total number of flight repairs	Launching conditions	Excess Pressure	Known Life Duration	Remarks
VUVR	1	1	acceptable	65	12 days	
NLNG	1	1	good	65	41 days	
GNGS	1	26	average	20	3 days	launched simul-
CDCR	0	20	"	40	8 days	taneously at
UBUF	0	15	"	40	6 days	night
NCNP	0	9	"	40	4 days	
XLXG	0	0	excellent	67	2 days	Frost during flight
RBRF	0	0	"	60	6 days	
BVBW	1	19	"	70	3 days	Launched simul-
RCRP	0	1	"	70	13 days	taneously

TABLE II - Compared Performances of 10 Balloons (300 millibars)

Balloon	Number of leaks when unpacked	Total number of flight repairs	Launching conditions	Excess Pressure	Known Life Duration	Remarks
ULUG	1	1	good	65	32 days	
NBNF	0	6	acceptable	65	3 days	balloon recovered after a failure: pay load caught by an obstacle on take-off
KCKP	2	2	good	57	16 days	
GDGR	2	2	acceptable	50	44 days	
CLCG	0	0	"	45	2 days	failed immediately after take-off, probably due to recovery fitting
FVFW	1	1	average	55	54 days	
RNRS	0	0	"	55	52	
NVNW	0	3	excellent	50	46 days	balloon fatigued
BLBG	1	11	"	50	28 days	" "
DNDS	0	0	"	50	5 days	
ZLZG	1	1	"	50	37 days	
DUDR			acceptable	50	5 days	
PLPG			"	50	8 days	
RLRG			"	50	6 days	
CDCR			"	50	43 days	

TABLE III - Compared Performances of 15 Balloons (200 millibars)

It was therefore demonstrated that it is practically impossible to launch pay loads longer than 50 meters in length. A first device (VUVR) with an overall length of 90 meters missed these obstacles only by a miracle, a miracle which was not repeated on the second release. It was therefore necessary to shorten the distance between the gondola and the float to 40 meters maximum. In a general manner, for a normal gondola (5 meters beneath the balloon + 5 meters of antenna), the following is found: 19/

wind 0 to 6 knots -- ideal conditions

wind 6 to 10 knots -- conditions acceptable with some precautions

wind greater than 10 knots -- acrobatic conditions

It was important to release the balloon very quickly without holding it against the wind because the fabric of the bag becomes fatigued very quickly under these conditions. A balloon (NBNF) caught on departure and the bag remained fastened for approximately 15 minutes and was shaken by the wind: 6 large leaks developed during this short period.

5. BEHAVIOUR OF THE BALLOONS IN FLIGHT - FROST 22/

Since the data gathered by the various stations in the receiving network is still being assembled at the time of this report, the information mentioned here is based solely on the data recorded at MILDURA.

In general, the life duration of the balloons launched during the course of EP-IV was appreciably longer than that observed during the preceeding field exercises but nevertheless less than that of the GHOST flights. It is certain that the necessity of gaining respect for a program of pay load launchings and the need at the same time to accomplish some tests requiring the presence of recorders on the inside of the balloon does not favor prolonged life span. There was a particularly noticeable amount of fatigue in certain bags before the launching when they were held while waiting for favorable meteorological conditions. A detailed analysis of the life span will be shown in a definitive report.

On the other hand evidence has again shown the rapidity and the importance of the frosting phenomena. Four balloons were launched at night (21 H and 22 H) through a thin cloud covering (5/10). This covering was sufficient to frost the four devices to various degrees (Figure 2). It should be noted that there were very evident leaks in three balloons out of the four. This experiment leads us to predict as very risky the success of night launchings except in a perfectly clear sky. Therefore, launchings at night for operational flights should be avoided. 23/

One flight (XLXG) furnished us a perfectly demonstrated example of frost in flight at the 300 millibar level since the vehicle passed through a rather dense cirrus. This balloon which carried a reflecting cap for raising the temperature of radiation balance, accumulated approximately one kilogram of ice in 30 minutes (maximum). It then fell to approximately 4000 meters but the water which overloaded it evaporated in the very dry atmosphere and the device rose immediately to its normal level (to almost 20 millibars). This exceptional recuperation during the course of the fall furnished a definitive demonstration of the reality of the phenomenon of frost. It permitted, in addition, the precise measurement of the speed of ice accumulation and arrived at the existance of two distinct causes of frosting:

-- Frost from water vapor in an atmosphere which is clear but close to saturation. This type of frost is produced at night on balloons of ordinary mylar, whose radiation balance temperature can reach 6° below the ambient temperature This frost, comparable to the phenomenon of "white frost" builds slowly and should not overload a balloon in a catastrophic manner in less than 12 hours. This phenomenon is definitely eliminated by the addition of a reflecting cap on the top of the balloon 24/ which has the effect of raising the temperature balance from 5° to 12° C.

-- Frost in a cloud of ice crystals (cirrus). This phenomenon, incomparably more rapid than the preceeding, includes the fixation of already existing crystals on the exterior wall of the balloon as its temperature nears the ambient temperature in the midst of an opaque cloud. The phenomenon is probably caused by the vertical fall of the crystals under the action of a weight (such as the snow). It "snows", therefore, on the balloon and the ice accumulated in this manner can produce the drop in half an hour, such is the nature of the surface of the balloon, reflecting or not.

These phenomena are the object of a detailed study prepared with a view to publication (Appendix I).

The rapidity of the frost leads us to arrive at the impossibility of of "passive" defensive processes such as radiation control, aerostatic floats ... Undoubtedly the only help here is in escape either aloft as V. E. Lally proposes, or down with a marine float assuring the chance of survival in case of a drop into the sea.

6. TEMPERATURE MEASUREMENT 25/

By virtue of the restrictions imposed by CNES on the flights of permanent sounding balloons in the Northern Hemisphere, EP-IV was the first field exercise during the course of which the temperature of the air from such a

tracer following an average discharge was attempted for measurement. The device comprised essentially a miniature STC thermistor, type P 23, included in an oscillator with variable frequency following the sensitive resistance of the element. This device had been tested in the laboratory with no apparent difficulty and also at Aire-sur-l'Adour during the course of a pseudo-sounding flight where the temperature of the air recorded by local meteorological sounding was measured with fine precision.

Observations

The temperature of the air measured during the ascension by means of a ventilated thermistor decreased regularly and recorded values completely comparable to those of nearby meteorological soundings (ADELAIDE) (Figure 3).

The situation changed completely when the balloon stabilized itself at the ceiling: the "outside temperature" signal showed some very rapid fluctuations (firm for a period of some seconds and very intense when some apparent temperature variations of 8° to 10° C. at a 300 millibar level and 12° to 15°C. at the 200 millibar level were registered (Figure 4). Simultaneously, the 26/ temperature measured in the same manner on the inside of the balloon, therefore with a total absence of ventilation, is perfectly stable.

These very large fluctuations were first attributed to the proximity of the gondola, without doubt too close in the first flight (flight VUVR). But the effect was the same if the thermistor was further removed from the gondola. In the case represented in Figure 4 (flight ULUG) the measurement of the air temperature was taken at the extremity of a 1.50 meter arm. The same measurement at 10 meters beneath the gondola indicated essentially the same fluctuations.

Two flights with fuel cells launched at night verified first that there is very definitely a radiation effect (no fluctuation during the night) and secondly, that the minimum measured during the day actually corresponds to the ambient temperature of the air (Figures 5 and 6).

To measure the ambient temperature from a sounding balloon (i.e. without ventilation) obviously posed a problem very different from the one posed by radio soundings. In this last case, in fact, one simply eliminated the power received from solar rays by placing the element sensitive to shadow in a duct where the ambient air was forced to circulate by the movement of the sounding. Something such as this was not possible at the ceiling since a thermistor protected by a screen sufficiently envelopping would measure the 27/ radiation balance temperature of the screen as well as that of the air. It was therefore necessary either to leave the element sensitive to the air free and exposed to the solar rays or to produce a forced ventilation.

The first solution was "a priori" more simple and preferable. It did not pose an insoluble problem in connection with the radiation effect on the temperature of the thermistor itself. A STC element, type 25, has a diameter on the order of 0.4 millimeters; it would, therefore, absorb a force of 0.15 milliwatts under the most intense conditions of insolation (200 millibars) supposing its surface was perfectly black. This supplemental energy should be dissipated into the air (by conduction and convection) and, therefore, produce an elevation in the temperature of the element of approximately 1.5° C. Even though sensitive, this loss is much too small to explain the observed fluctuation.

This is not the same, however, for the actual mounting of the STC thermistor (Figure 7). On this subject it is interesting to compare the heating of the surface of the different geometric forms receiving a flux of energy αE per unit of surface (E = lighting, α = absorptivity). This is approximately:

$$\text{Sphere:} \quad \Delta T \simeq \frac{\alpha E r_o}{4k} . \qquad (1)$$

$$\text{Cylinder:} \quad \Delta T \simeq \frac{\alpha E r_o}{\pi k} \log \frac{1}{r_o} \qquad (2)$$

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$$\text{Thin plane:} \quad \Delta T \simeq \frac{\alpha E l}{2k} \qquad (3)$$

where r_o is the radius of the object and l the distance to which it is acknowledged that the temperature is equal to the ambient (l ≃ 5 to 20 millimeters). For a STC P 23 bead with a 0.2 millimeter radius, completely absorbant (α = 1) the following is found: $\Delta T \simeq 1.5°$ C. For an equally absorbant barrier (α = 1) where the radius r_o = 0.4 millimeters, $\Delta T \simeq 8°$ C. is obtained, or a heating on the order of the size of the positive fluctuations observed in flight.

It has been concluded, therefore:

(a) In a perfectly calm atmosphere (thermistor on the inside of the balloon), the radiation heating of the mounting produces a stable convection current which irrigates the thermistor with air whose temperature is equal or very close to that of ambient temperature.

(b) In a turbulent atmosphere (this may be, in fact, micro-turbulence with very little intensity around the balloon), this convection flowing is not stable and streams of hot air (+ 8° C.) and the

ambient temperature pass alternately over the sensitive element.

(c) There exist "a priori" two ways to eliminate these fluctuations. /29 The first consists in mounting the thermistor on a transparent support which would absorb only a very small fraction of the solar radiation. The second consists in releasing around the sensitive element a stable and reproducible current of convection.

The first method was tested at MILDURA with the resources available to the mission: a thermistor was detached from its regular support and soldered to two enamelled copper wires (2/10 millimeter), these being fixed to a leaf of mylar taken from a balloon. The recording of the temperature (flight DUDR) (Figure 8) shows that:

-- the fluctuations are non-existent before sunrise,

-- the fluctuations were reduced in relation to those observed with the preceding mounting,

-- the fluctuations were relatively greater in the morning when the solar rays hit the surface of the mylar support which hung vertically in a perpendicular position. Toward noon, on the contrary, the sun was very high (80° C.) and the incidence of the rays on the mylar was weak: the fluctuations were, therefore, reduced.

By using α = -.15 and l = 10 millimeters, the heating of the mylar /30 surface can be calculated to be approximately 20° (comparable to the loss measured between the temperature of the helium and that of the ambient air). This is, nevertheless, still excessive by at least a factor of 10. This solution, therefore, requires a mounting in which the absorption does not exceed 1% of the incident flux.

The second method was also attempted during the course of flight NLNG by placing a thermistor on the inside of a black spherical ring (Figure 9). This surface played the role of an umbrella protecting the thermistor from solar radiation when the height of the sun did not exceed 55°. This surface was also considerably hotter than the ambient temperature and therefore covered the device with an ascending convection current irrigating the thermistor. A perfectly stable, though slightly excessive, temperature was recorded since the thermistor was in the shade and contrariwise, there were some fluctuations as great as in the other flights as soon as the solar rays reached the sensitive element.

Results of thermal measurements

In spite of the difficulties mentioned above, the temperature of the radiation balance of the different parts of the equipment under sounding flight conditions can be estimated with a precision of ± 1 to ±2. These

temperatures are expressed below as the loss in relation to the ambient temperature. /31.

OBJECT	CONDITIONS	T
"Transparent" mylar balloon - diameter 2.5 m	level 300 mb day	+10 at +12° C
	" " night	- 1 at - 6° C
	level 200 mb day	+18 at +20° C
Mylar balloon with upper reflecting cap diameter 2.5 m	level 300 mb day	+18 at +20° C
	" " night	+ 6° C
White plastic sphere diameter 40 cm	level 300 mb day	+22 at +25° C

TABLE IV

7. PERFORMANCE OF THE EQUIPMENT /32

The flight exercise, EP-IV, was the first occasion using the new radio-electric beacon developed by CNRS following the halting of the preceding flight of gondolas (EP-I) judged to be dangerous in the event of collision with aircraft. This new beacon was developed after a series of impact tests on glass windows of NORD 262 from components and sub-assemblies. These tests have led:

-- to the adoption of a structure in the form of a ring limiting to 15 grams the mass of a circuit element capable of hitting an airplane,

-- eliminating the logic circuits in the conventional components and replacing them with integrated circuits. This modification required an increase in the power consumed by the logic circuits but this increased consumption is largely compensated by the new solar generator,

-- to replacing the solar generator with cells of Silicium by means of a pane of photovolt cells in a thin film of cadmium sulfur (CLEVITE). An experimental generator of cadmium Tellurure supplied by RADIOTECHNIQUE

was also tested in flight with complete success,

-- to replacing certain elements which were too heavy with some smaller components: power transistor, solar photometer, ... /33

These circuit modifications tied in to better controlled assembly procedures (electrical solder for integrated logic circuits, simplified cables dividing the principal functions into four different charts: measurement oscillators, frequency dividers, logic and formation of letters, HF transmitter) have considerably improved the reliability of the assembly and eased the manipulations on the ground. It should be noted that on the average one balloon a day was actually prepared and launched, which means that during one month double the number of those of the first field exercises EP-I and II were maintained.

The gondola and the recorders used will be the object of a detailed description in the second part of this report. It will be sufficient here to mention the difficulties encountered during the course of the field exercise as well as the solutions which were undertaken.

(a) Emission diagram of the antenna

A dipole $\frac{\lambda}{2}$ pitched in the middle constituted the most efficient anntenna possible for this type of mission. Also, it was necessary to use a longer antenna for experimental flights ULUG, NBNF, NLNG, and KCKP in order to be able to introduce a thermistor recorder on the inside of the balloon through the upper valve (Figure 10). Therefore, a 20 meter (1 λ) antenna /34 was used pitched at $\lambda/4$ from the lower extremity. This antenna always radiated extremely poorly on a horizontal plane since the diagram for theoretical transmission was precisely nullified on the plane for symmetry.

There resulted an acceptable short range level of reception which was however extremely weak at medium range. . The reception is such that these four balloons are but only rarely heard. This is why the NLNG and KCKP balloons launched simultaneously on 27 December 1967 made a trip around the earth and were heard at Mildura on the 10 and 11 January without any of the stations in the network being able to record their passage. Similarly, the ULUG balloon which was considered lost three days after launching was identified briefly by stations at LIMA and BUENOS AIRES after 31 days of flight.

(b) HF Connection

The tests in the laboratory or in flight at Aire-sur-l'Adour (when the height of the sun does not exceed 40°) did not reveal before the field exercise an excessive connection problem between the HF transmission (15 MHz) and the 40 KHz oscillator of the differential manometer. This connection produced a cut off of the beacon when the HF power reached a level corresponding to a /35

solar height of 40°. In other words, the transmittor was cut off during the major portion of the day and the corresponding balloons (KCKP, GNGC, CDCR, UBUF and NCNP) could be heard only:

-- in the morning (sun between 20 and 40°),

-- at noon if the shadow of the balloon fell on the solar pane, thus reducing the HF level to a sufficiently low value,

-- at night (sun between 40 and 20°).

This defect was eliminated on all of the other flights by disconnecting the 40 KHz oscillator and the stage set in a corresponding manner.

(c) Temperature of the gondola

A hood of white plastic material was planned in order to maintain the temperature of the gondola at a level appreciably more elevated than the ambient temperature for flights at 200 mb (T_a = -60°C is typical). In fact, this precaution was demonstrated to be too efficient since in two cases at least the temperature in the completely closed gondola was raised to +30 or +40°C. at noon, or 90 to 100°C. above the ambient temperature. Since the circuits were not designed to function above average temperatures errors resulted in the coding of letters on these balloons. A reasonable functioning temperature (0 to 10° C.) is obtained by cutting a hole three centimeters in diameter in the upper portion (solar generator) permitting the release of the hot air. 36/

(d) Photometric solar "Sextant"

A new photometric "sextant" was used on which the variation of measured flux as a function of the height of the sun depended not only on the visible section of the entry window, but also on the diffusion in the length of the tube (white plastic) which separated the red filter from the photosensitive cell (CLAIREX CL 903). The advantage of this new placement is the approximate linearity of the characteristic solar height - telemetered frequency (Figure 11). It was also observed on the first flights that there was an exagerated dispersion of the signal in relation to the time which resulted because of the anisotropy of the CLAIREX detector itself. This anisotropy introduces in the height signal of the sun a veritable pseudo-periodic modulation linked to the rotations of the gondola around the vertical (Figure 12). This parasitic effect was remedied by adding an opal diffusing glass in front of the CLAIREX cell (Figure 13).

8. CONCLUSIONS

/37

We are limited here to technical conclusions which immediately from this fourth balloon field launching exercise, even before the data recorded by the CNES listening network have been examined. The scientific results concerning the dispersion of the pairs of balloons will be presented in a later publication.

It appears at first extremely difficult, in fact impossible, to require a launching station to accomplish a regular rhythm of releases, even in a site "a priori" as favorable as MILDURA, situated in a sub-tropical desert zone. In fact, the meteorological conditions and particularly the cloud coverings intervene in a decisive manner. In particular the nocturnal launchings are normally prevented, except if the atmosphere is perfectly limpid. The crossing of a cloudy layer while ascending to the ceiling is always hazardous (even during the day) and should be avoided as much as possible considering the reduced ascending power of the EOLE balloons.

On the other hand, the force of the wind on the ground is also a determining factor; there is always a threshold, which depends on the nature of the installations at the launching site, above which the release becomes acrobatic and therefore hazardous. Under the precarious conditions of the EP-IV exercise, this threshold was placed at five meters per second and the /38 periods favorable for launching were, as a consequence, very rare. A good shelter for preparing and inflating the bags, itself protected by a sufficently large structure, is therefore absolutely necessary at every possible operational station.

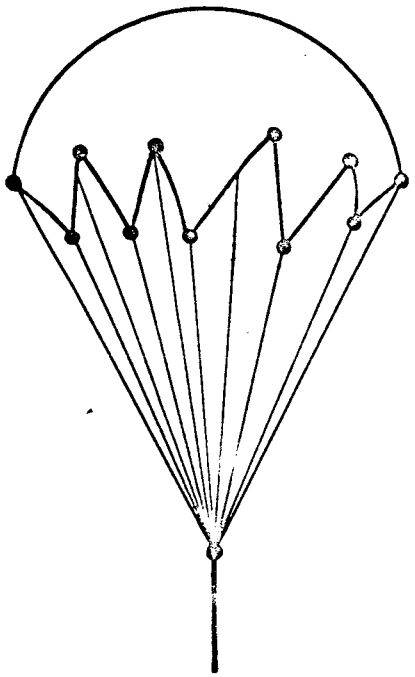
The experience of storage in a non-rigid shelter has shown how fragile and how sensitive to fatigue the material actually is (mylar 25 µ + 25 µ). It is probable under these conditions that the balloons would be seriously fatigued, even pierced, during the course of launching operations which always require rapid and therefore rough handling (except in the total absence of ground wind). It is therefore indispensable:

-- either to appreciably improve the resistance of the material to repeated folding and rubbing,

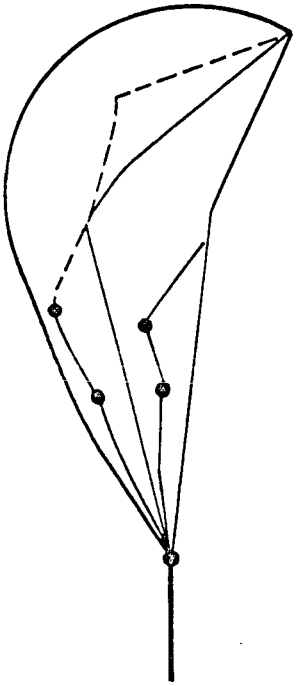
-- or to develop a calibrated valve or a completely different system (a thin and tight "helium chamber" in the main bag) which would permit the launching of the completely inflated balloon in a spherical form.

It is only in a spherical form that the straining caused by the rubbing of the material can be prevented and that the balloon can be kept in a hold situation without risk of damage.

These developments on more resistant balloons indispensable to the success of the EOLE experiment now constitute a critical element of this CNES program.



BALLOON WITH NORMAL ASCENDING FORCE (STAGE C)



BALLOON IN BALANCE HALF INFLATED (STAGE B)

Figure: 1.

POINTS WHERE LEAKS WERE OBSERVED AFTER STORING IN A NON-RIGID SHELTER.

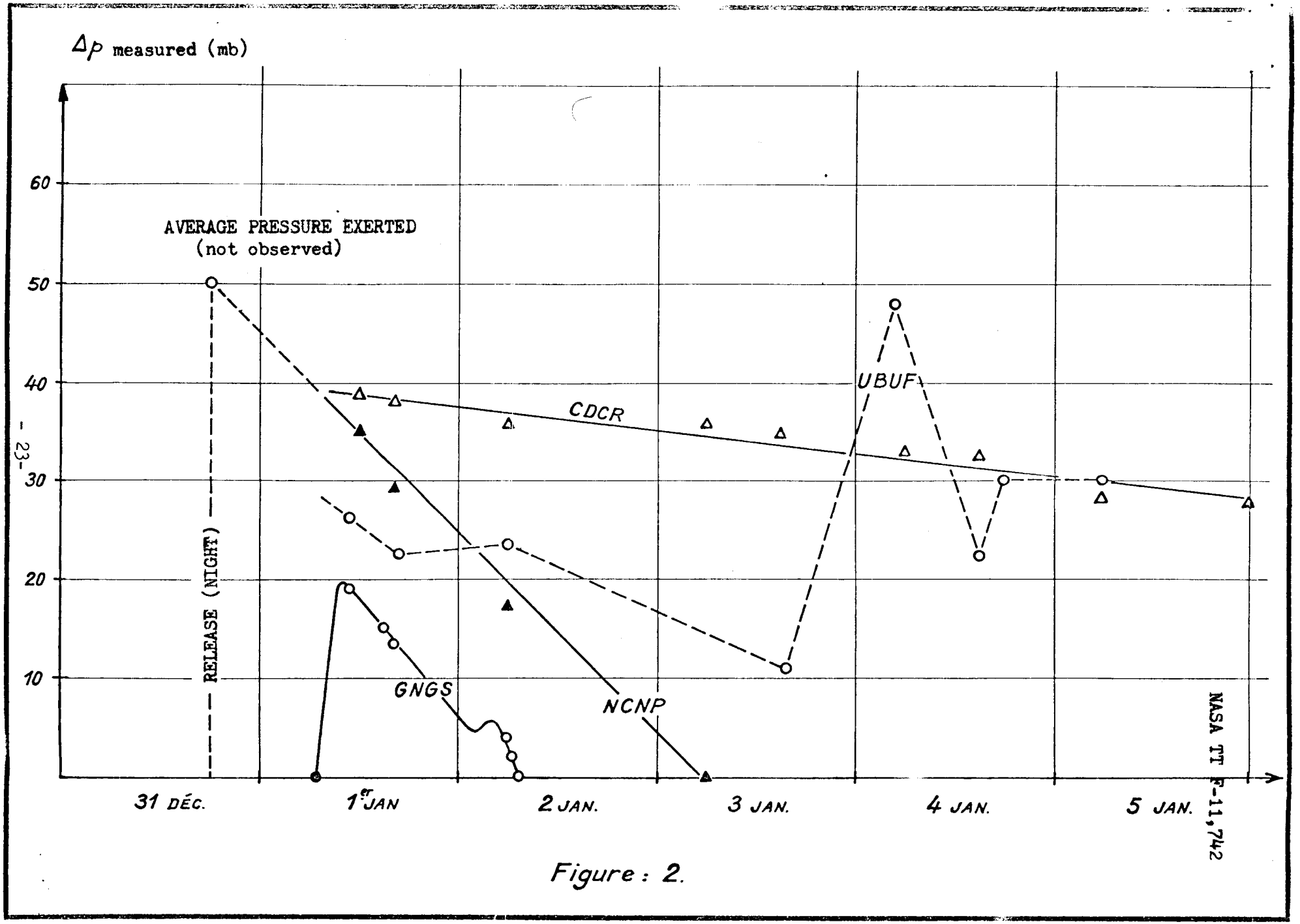

Δp measured (mb)
60
50
40
30
20
10
AVERAGE PRESSURE EXERTED
(not observed)
RELEASE (NIGHT)
CDCR
UBUF
GNGS
NCNP
31 DÉC.
1er JAN
2 JAN.
3 JAN.
4 JAN.
5 JAN.
NASA TT F-11,742

Figure : 2.

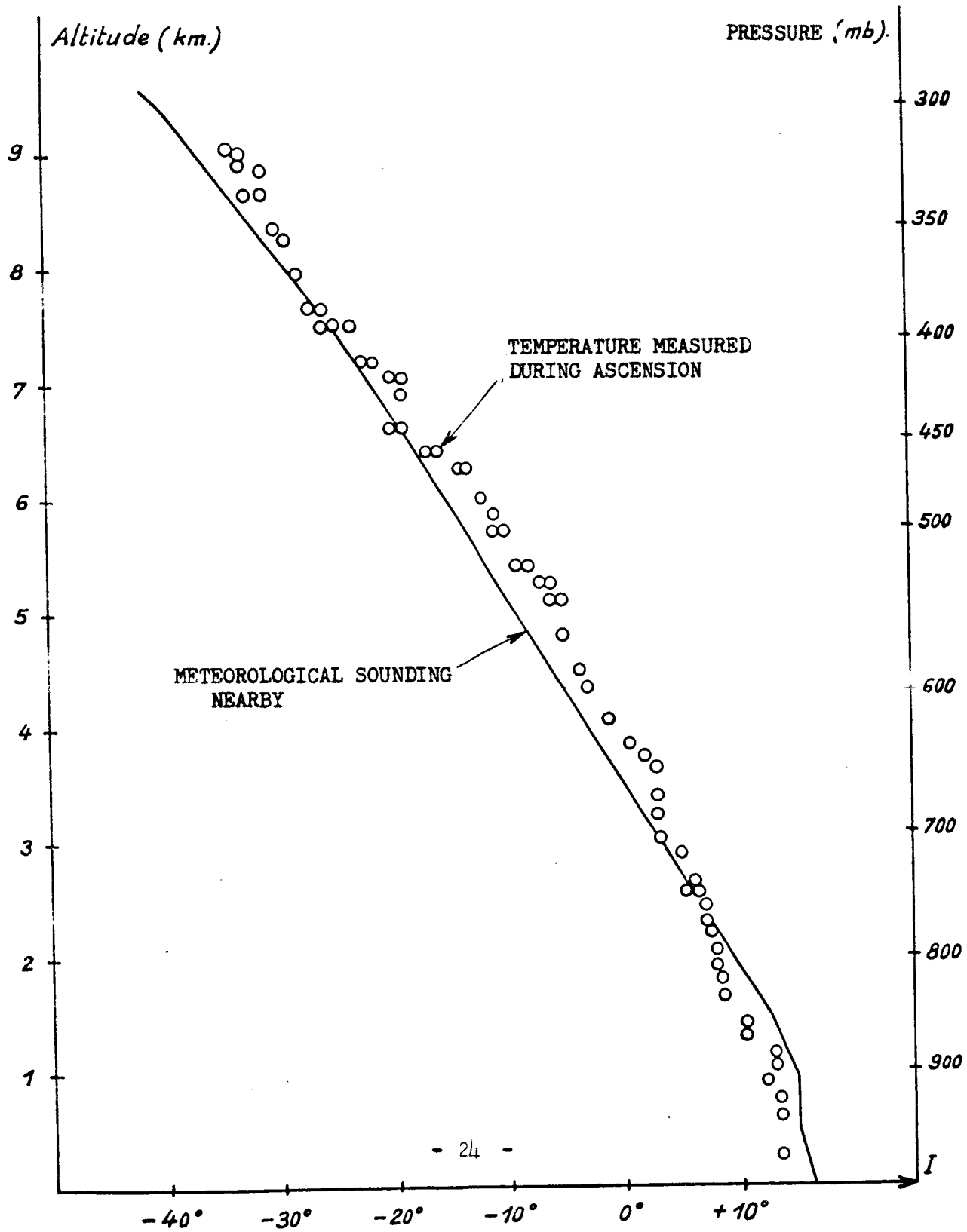

Altitude (km.)
PRESSURE (mb).
9
8
7
6
5
4
3
2
1
300
350
400
450
500
600
700
800
900
TEMPERATURE MEASURED
DURING ASCENSION
METEOROLOGICAL SOUNDING
NEARBY
-40°
-30°
-20°
-10°
0°
+10°
I

Figure : 3.

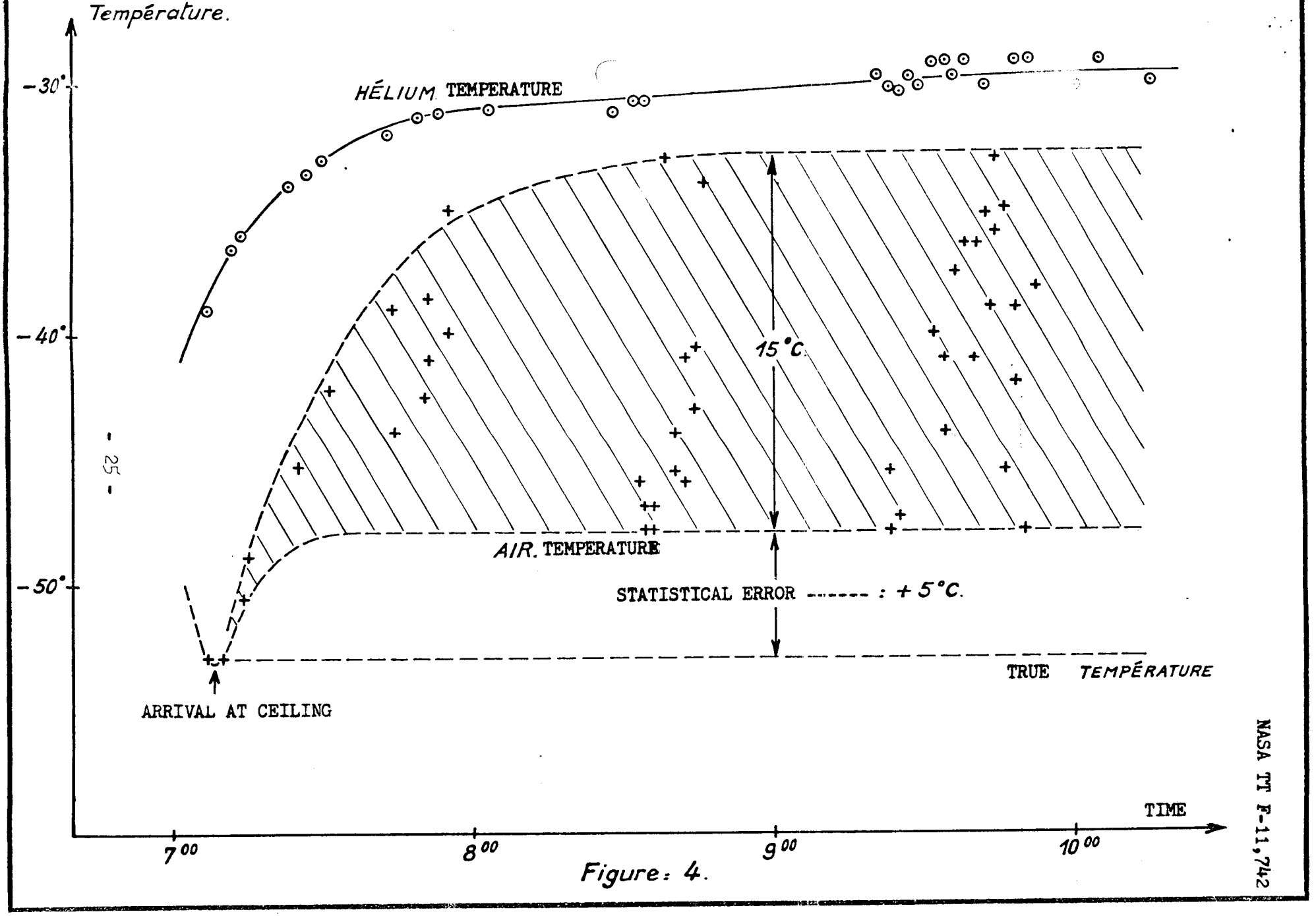


Figure: 4.

NASA TT F-11,742

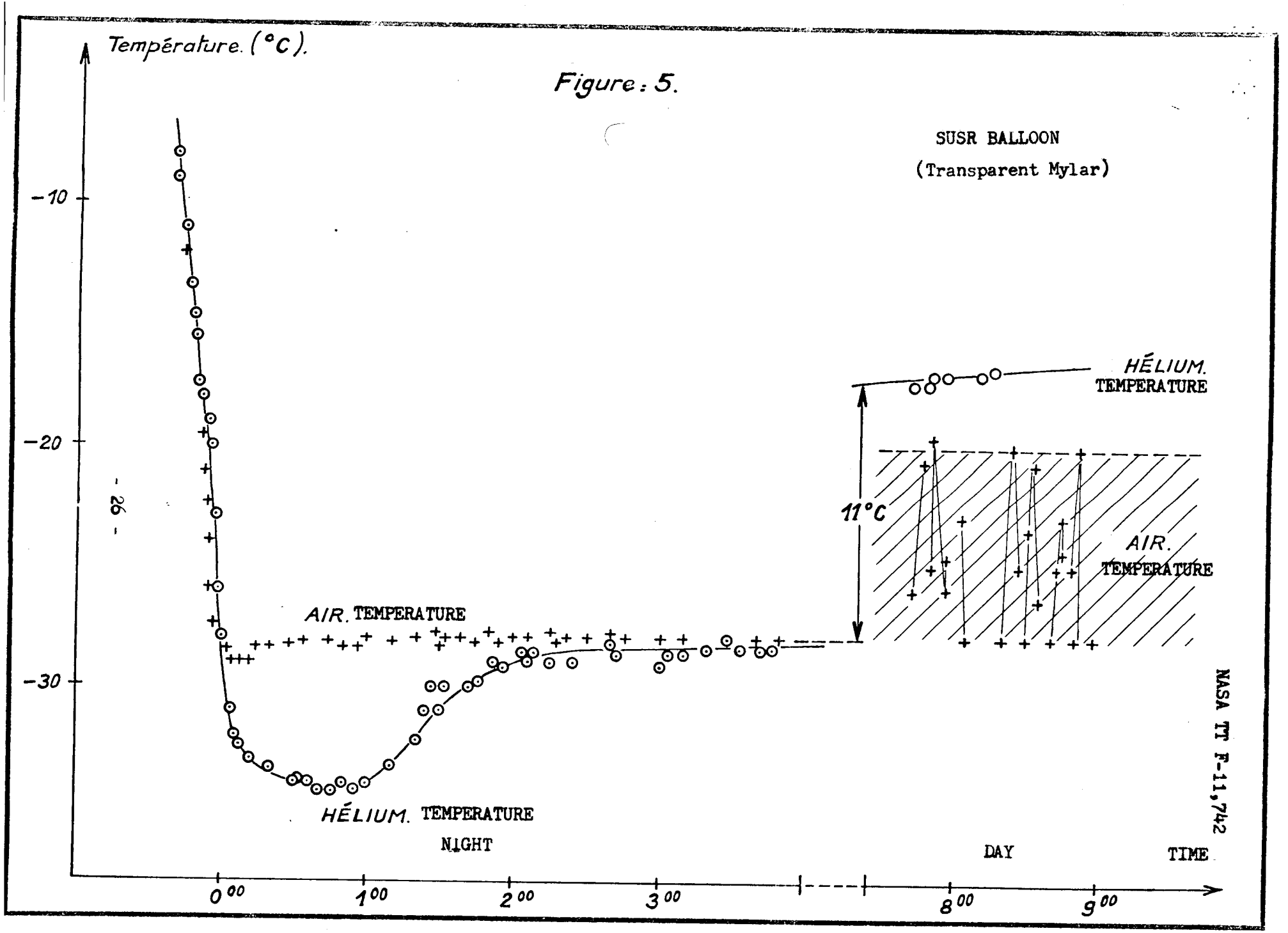

Température. (°C).
SUSR BALLOON
(Transparent Mylar)
-10
-20
-30
HÉLIUM. TEMPERATURE
11°C
AIR. TEMPERATURE
AIR. TEMPERATURE
HÉLIUM. TEMPERATURE
NIGHT
DAY
TIME
0 00
1 00
2 00
3 00
8 00
9 00
- 26 -
NASA TT F-11,742

Figure : 5.

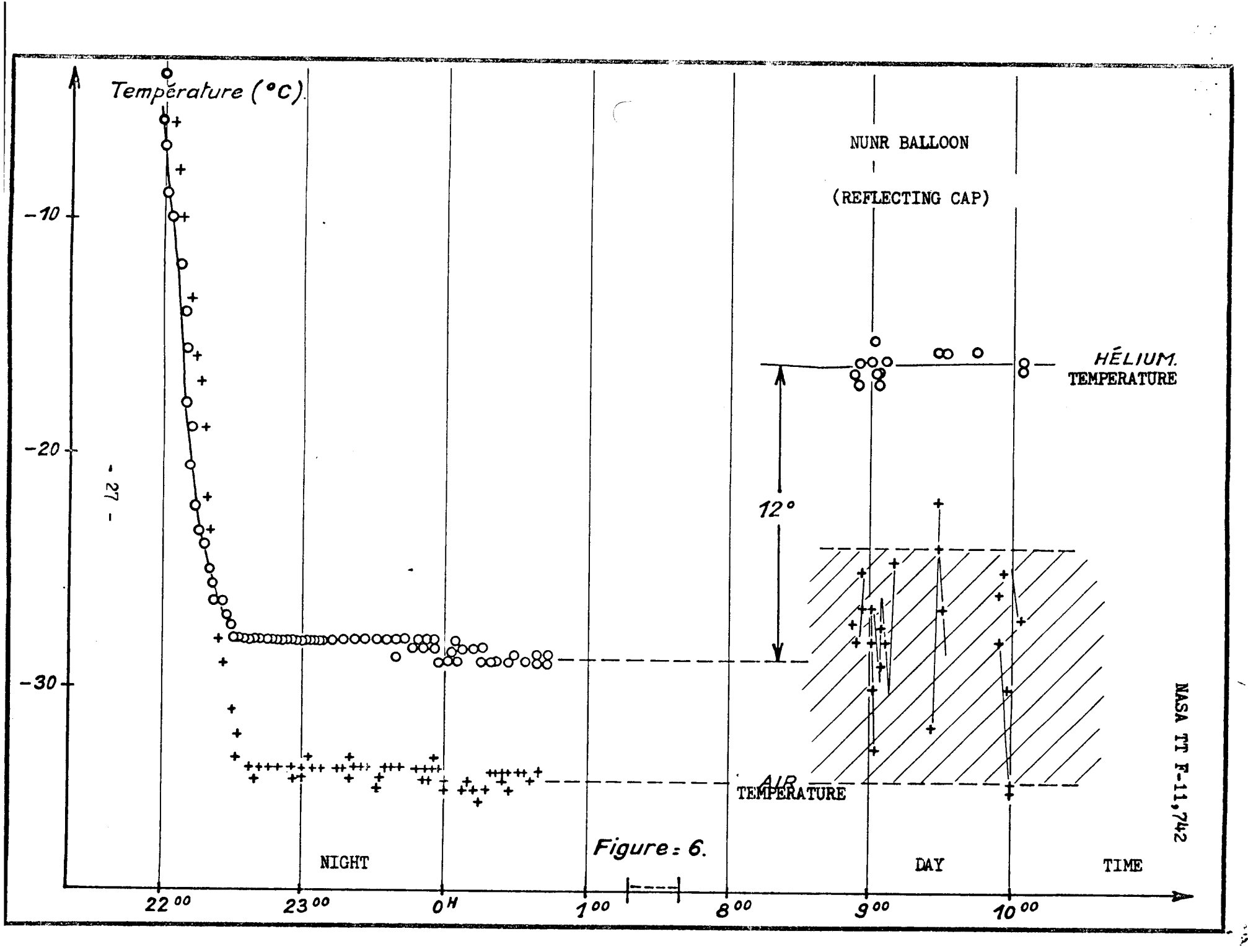

Température (°C)
-10
-20
-30
NUNR BALLOON
(REFLECTING CAP)
HÉLIUM.
TEMPERATURE
12°
AIR
TEMPERATURE
NIGHT
DAY
TIME
22 00
23 00
0 H
1 00
8 00
9 00
10 00
NASA TT F-11,742

Figure = 6.

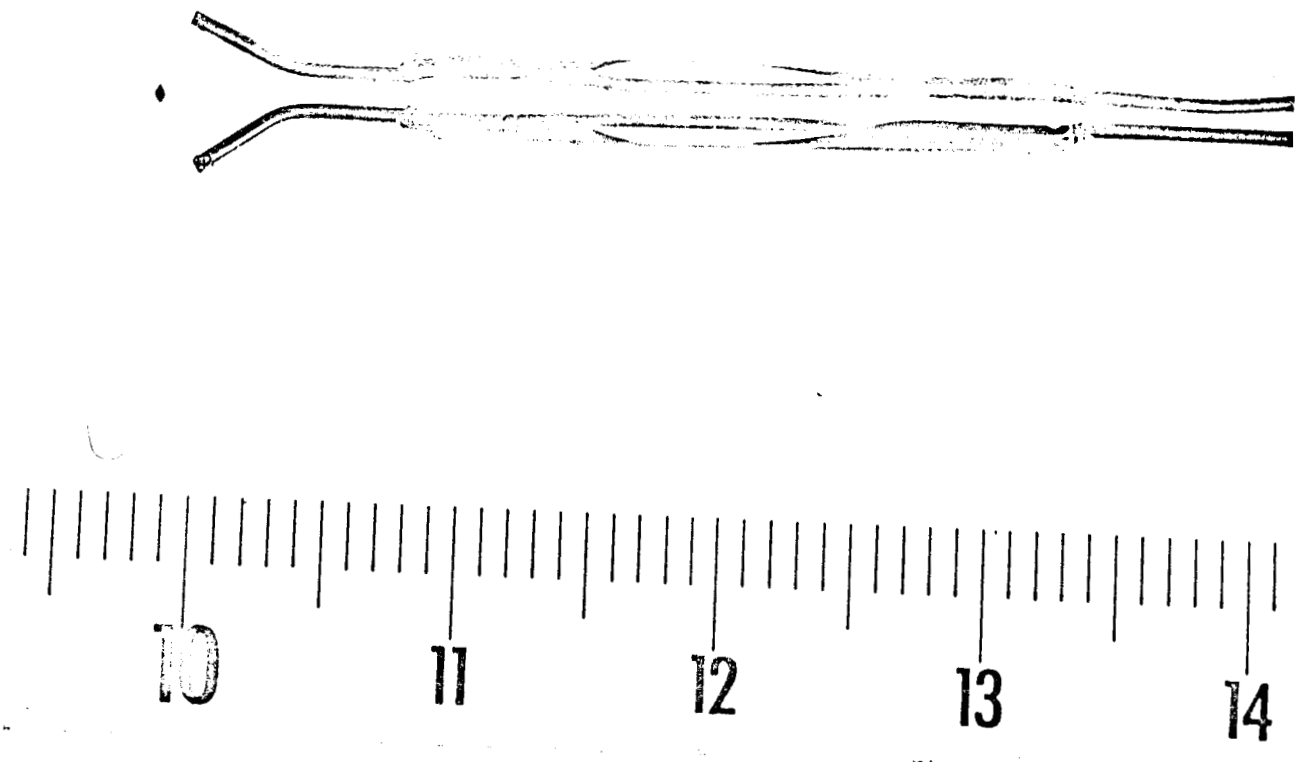


Figure 7 - THERMISTOR STC P23

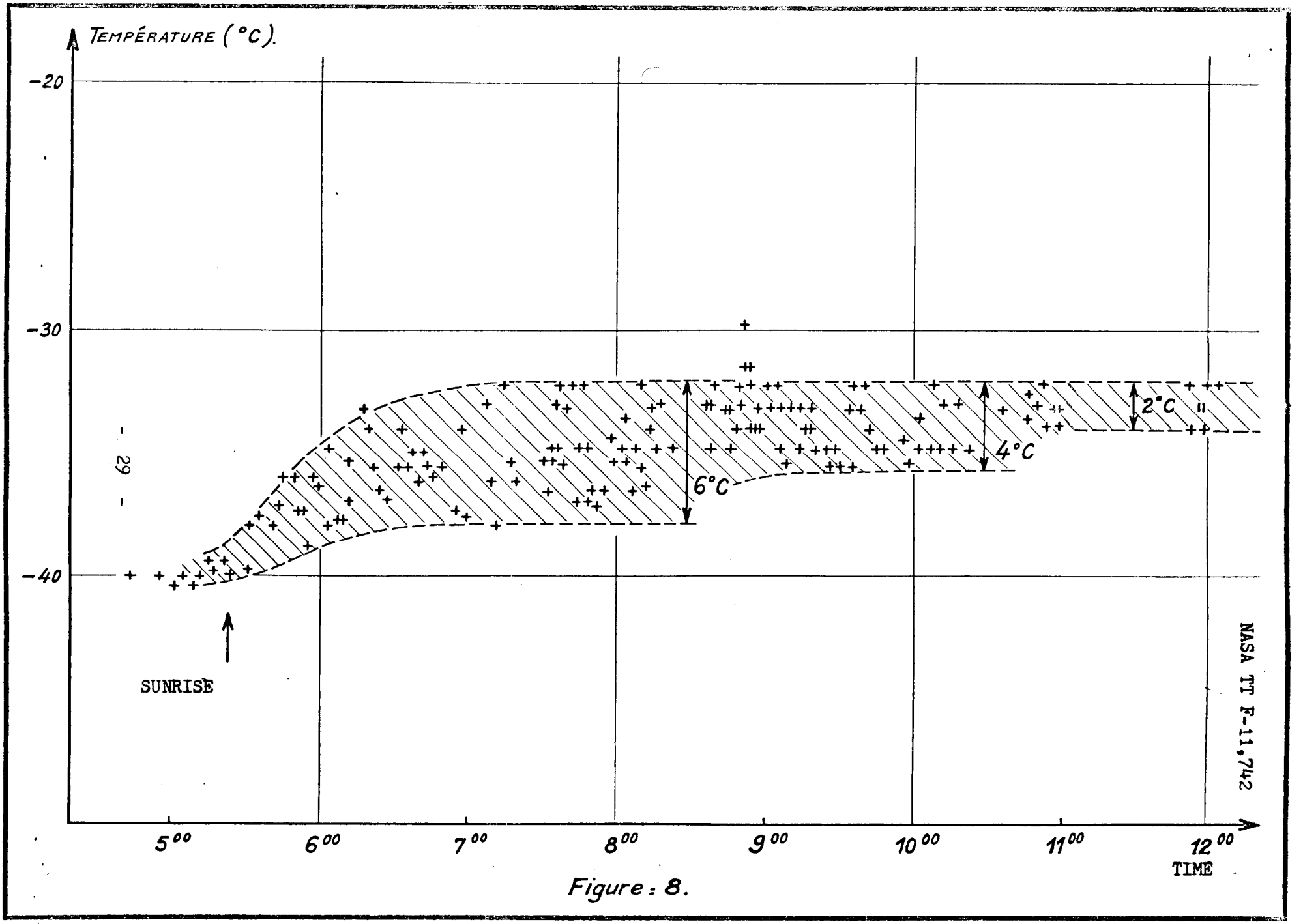

TEMPÉRATURE (°C).
-20
-30
-40
- 29 -
6°C
4°C
2°C
SUNRISE
5 00
6 00
7 00
8 00
9 00
10 00
11 00
12 00
TIME
NASA TT F-11,742

Figure : 8.

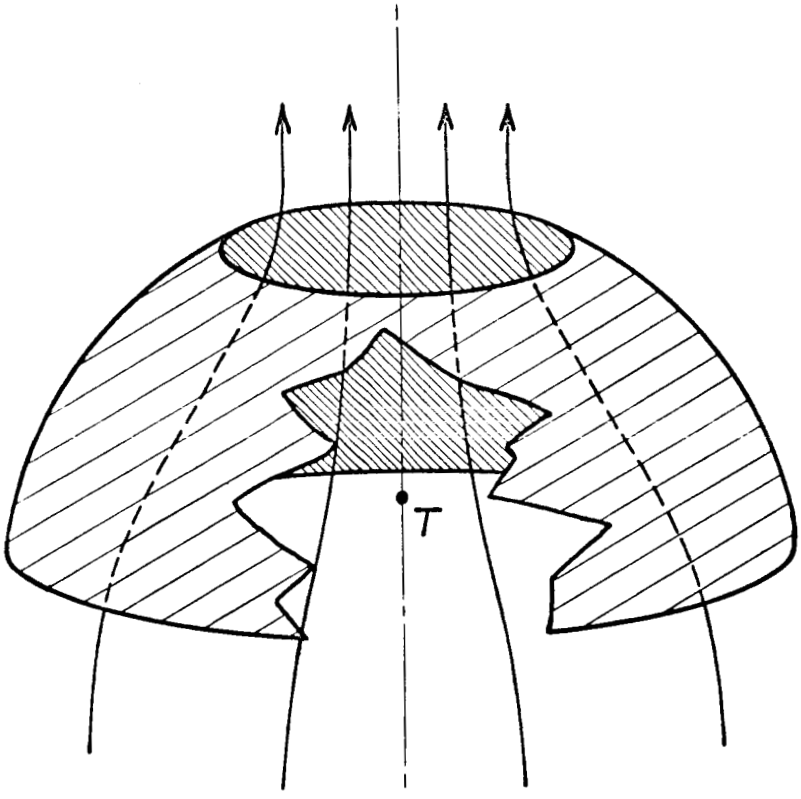
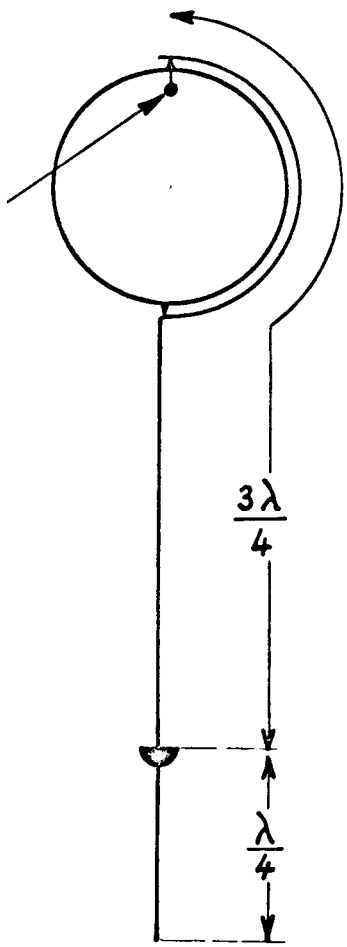
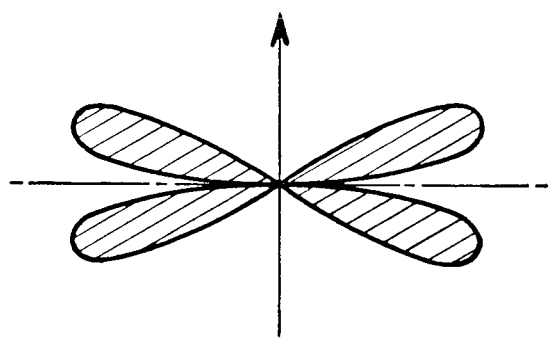


Figure : 9.





TRANSMISSION DIAGRAM

DIPÔLE λ.

Figure : 10.

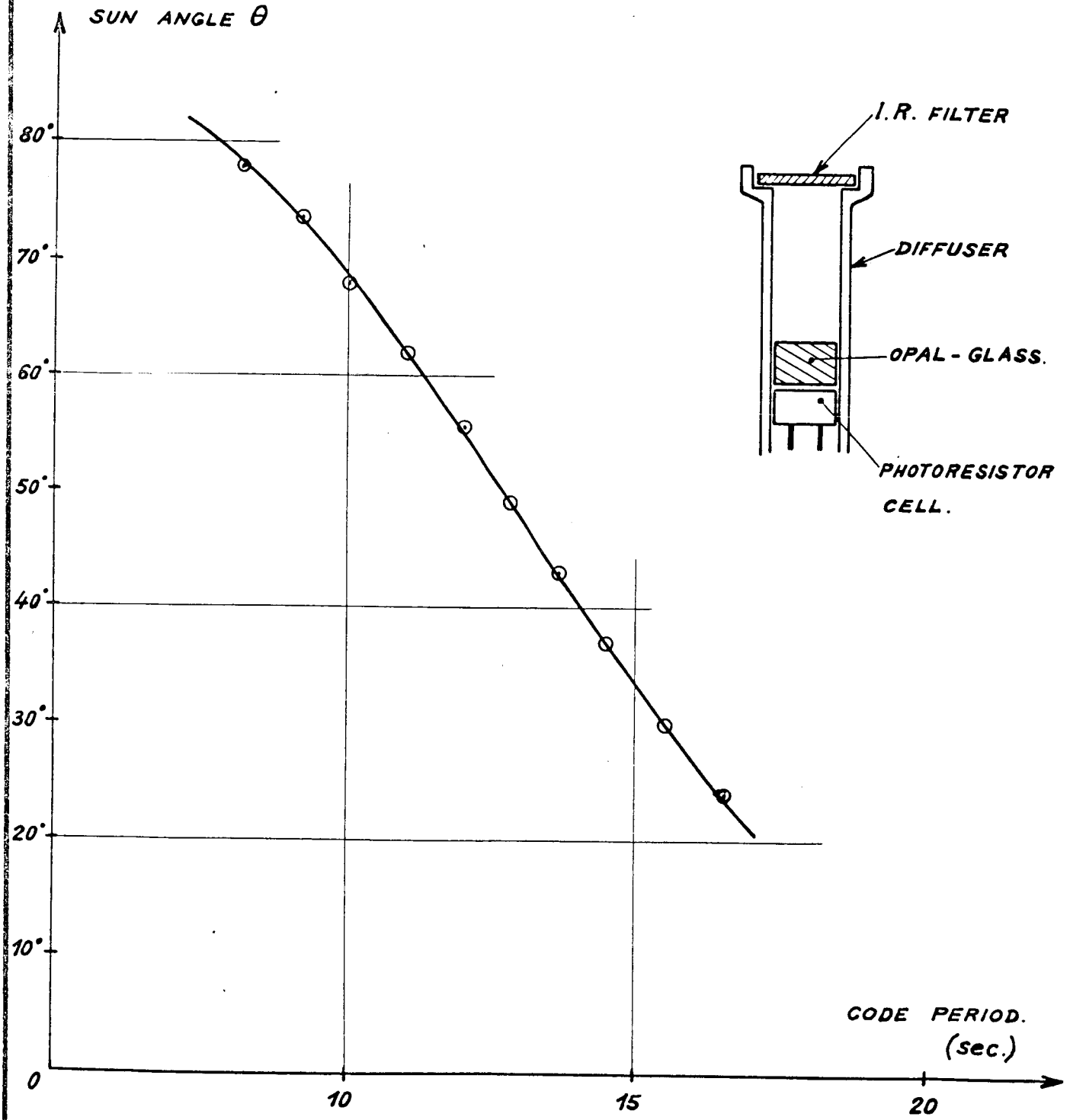

SUN ANGLE θ
80°
70°
60°
50°
40°
30°
20°
10°
0
10
15
20
CODE PERIOD.
(sec.)
I.R. FILTER
DIFFUSER
OPAL - GLASS.
PHOTORESISTOR
CELL.

Figure : 11

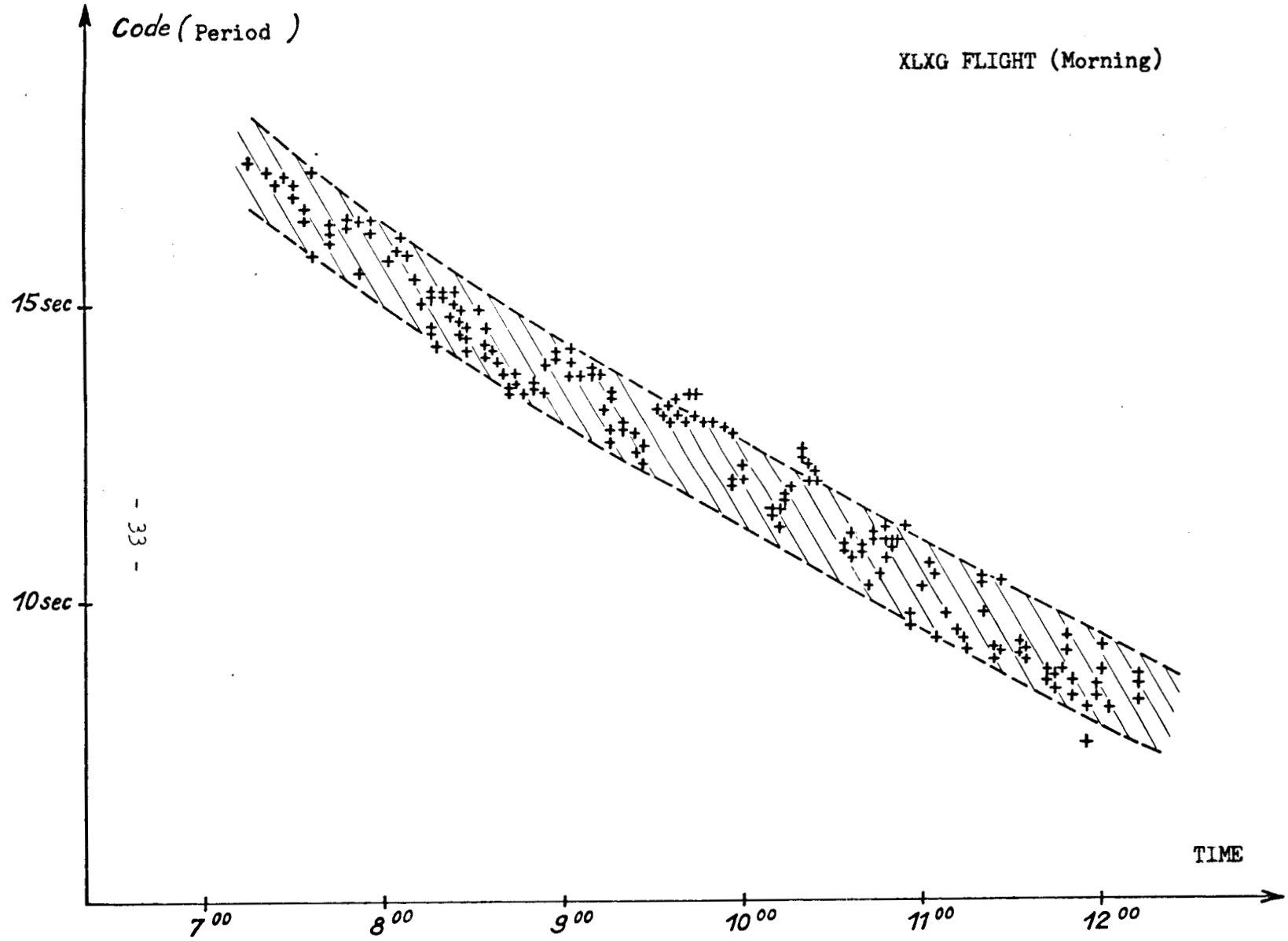


Figure : 12.

NASA TT F-11.742

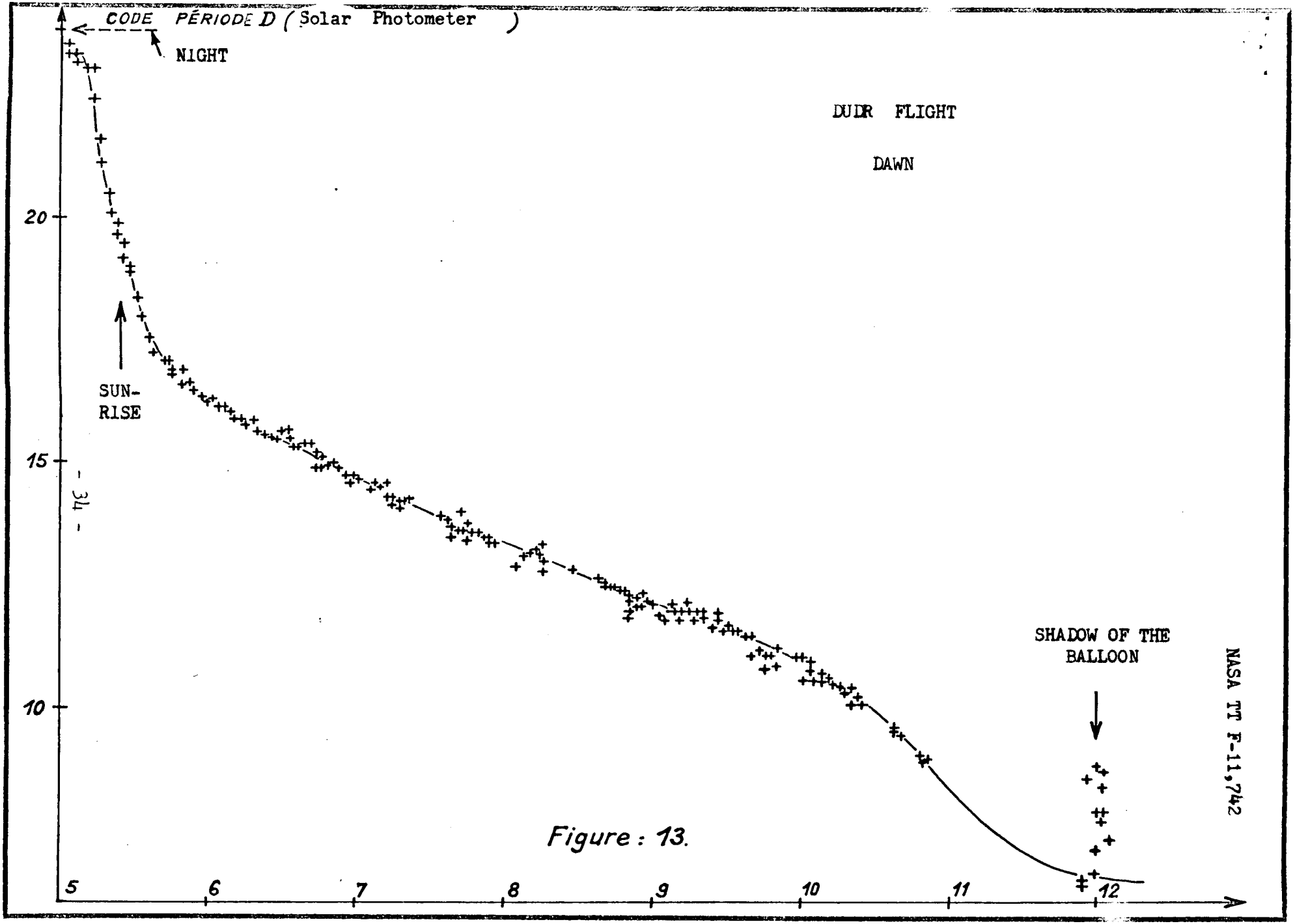

CODE PÉRIODE D (Solar Photometer)
NIGHT
DUDR FLIGHT
DAWN
SUN-
RISE
SHADOW OF THE
BALLOON
NASA TT F-11,742
20
15
10
5
6
7
8
9
10
11
12
A

Figure : 13.